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The Effectiveness of Unmanned Aerial Vehicle (UAV) for Digital Slope Mapping

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Abstract- This paper discusses the applications of unmanned aerial vehicle (UAV) for slope mapping and its important parameters including perimeter, area and volume of certain selected areas. Modern UAV able to take high quality image which essential for the effectiveness and nature of normal mapping output such as Digital Surface Model (DSM) and Digital Orthophoto. This photo captured by UAV will later transfer to Agisoft to generate full map of study area. Three locations in Kuantan Pahang are chosen (Sungai Lembing, Politeknik Sultan Ahmad Shah 'POLISAS' and Pahang Matriculation College) for slope mapping. With the help of Global Mapper, the measurement (perimeter, area and volume) of selected study areas can be determined easily and considered as the main interest in this study. In addition, another outcome of this study is, this modern method of mapping will be compared to traditional method of mapping which proven to be more effective in term of low costing, low time consuming, can gather huge amount of data within short period of time, low man power needed and almost no potential risk of hazardous effect to man. In conclusion, modern technology of UAV proves to be very effective for mapping in geotechnical engineering. Slope mapping help researchers and engineers to obtain slope measurement within short period of time compared to previous traditional method.

Indexed Terms- Unmanned Aerial Vehicle (UAV), Slope Mapping, Digital Surface Model (DSM), Digital Orthophoto

I. INTRODUCTION

Recently, the use of unmanned aerial vehicle in research study and commercial term are ending up progressively normal [1], [2]. According to Ismail *et al*. [3], geophysical surveys in mountains and natural terrains are normally challenging due to the site conditions, which may affect the quality of data acquisition. Unmanned aerial vehicle (UAV) or known as drone allow for the effectiveness of monitoring which cover large area of land and infrastructures within a very short time interval compared to conventional techniques [4].

1.1 History of UAV

Nowadays, the instruments used for data acquisition in geological topography have been rapidly improved. With the development of modern technology, the equipment used to gather all information related to earth surfaces becomes cheaper, smaller, accurate and can gather large amount of data within a short period of time [5]. Unmanned aerial vehicles ('UAV's) are also known by many other names, such as, unmanned aircraft system ('UAS'), remotely piloted aircraft ('RPA'), micro air vehicle ('MAV') (Beretta *et al*., [6]).

These devices are light, mobile, easily to operate, completely automated and providing access to almost unavailable study areas. Advances in UAV technology have enabled the acquisition of high-resolution and real-time aerial images for photogrammetry [7], [8]. An unmanned aerial vehicle (UAV) is normally an aircraft that launches and flies without a human onboard [9].

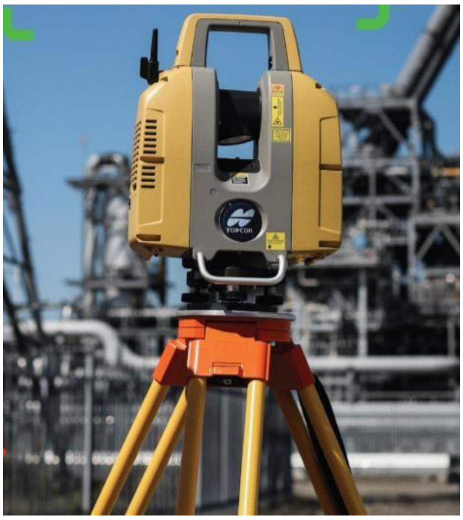
As suggested by Ibrahim [10], the first map was found in 2000 BC which is Babylon's clay tablets by Greeks and Romans. After that, the data was collected by surveyors in the field, it later drawn to maps by cartographers with printers generating paper maps. The measurement of electronic distance (EDM) explained on how quick it makes proper distance measurements. It also provided way to find the location of the shooting plane, which reduces the amount of measurement needed to produce several types of maps. Table 1 shows the disadvantages of using traditional method of mapping.

UAV has developed during the last decades. They operate remotely in the form of small platform, attached completely with camera and available as small or micro aircrafts. UAV photogrammetry provides information used for image stitching. Autopilot system guarantees planned flight path, camera triggered auto-control to take a picture at every waypoint. The greatest amount of information is contained in the video signal [11]. Thus, this modern technology will help in research and also commercial works which make work easier and faster. In this study, with the combination of data from UAV and established software provide researchers with important parameters and information about geological and topography of study area [12], [13].

With the help of UAV, the effectiveness of land monitoring together with existing infrastructures can be conducted within a short time period compare to conventional techniques, especially for urgent cases like natural disasters [14], [15]. Recent technological developments of unmanned aerial systems (UAS), including unmanned aerial vehicles (UAV) and data processing technologies, lead to extensive use of these techniques in various fields [16]-[19].

Table 1: Disadvantages of mapping using traditional method (Ibrahim [10])

Authors	Types and Disadvantages
Fitzpatrick [20]	Manned Aircraft (this method of mapping and volume consume lot of time, cost but less accurate) 
Sebbane [21]	GPS Point Survey (Inaccurate and not very dense in information)

Beretta *et al*. [6]	Laser Scanning Survey (Expensive, low quality mapping, and time consuming) 
Siebert and Teizer [22]	Tachymetry (Theodolite) Surveying (Time consuming, need a lot of workers and inaccurate in results) 

1.2 Slope Formation

There are two types of slope known as primary and secondary slope [23]-[27]. Primary slopes are formed by tendency to promote relief while secondary slopes are formed by process tending to decrease relief. The origins of primary slopes can be the tectonic which is fault scarps, depositional such as glacial moraines, drumlins and alluvial fans, erosional like glacial and riverine valleys and human activity such as blasted rock slopes, hydraulic mining and tailing pipes. On the other hand, secondary slopes evolve from the erosion and modification of primary slopes

1.3 Slope Stability

Slope stability is the ability of the soil slope to prevent failure and movement [28]-[33]. Soil slope stability can be defined as the balance between shear stress and shear strength. Angle of slope and the strength of materials on it can affect the stability of slope.

As stated by Alizan [25], the aim of slope stability analysis is to assess the safety design of man-made or natural slopes and the equilibrium conditions. It is essential to check the stability of the slopes as the result of a slope failure may lead to loss of life and property. A safe and economical design of slope is now possible with the development of modern method of soil testing and stability analysis.

1.4 Slope Hazard

As stated by Huat and Mariappan [34], there are three conditions for the application of the stated methods of slope hazard identification known as landslide assessment, the availability of information and the type of landslide assessment. For landslide assessment, a small scale of study will implement simple methods such as heuristic methods (expert judgement approach) and deterministic method (common slope stability analysis approach) for slope assessment. These kinds of analysis require enough failure history to obtain an accurate hazard classification [35]. There are two categories which are linear based assessment and area based assessment exists in landslide assessment.

1.5 Measurement of Slope Hazard

The geometric factors such as slope height, slope angle, slope profile, position and size of berms and the angle of natural slope above cutting affect the stability of slope [36], [37].

1.6 History of Slope Failure

According to Ishak [38], one event took place at Hidayah Madrasah Al-Taqwa orphanage at km 14 Jalan Hulu Langat, Selangor. This tragedy occurred during a long spell of daily torrential rainfall event which suddenly triggered the landslide, wrecked the houses and killing 16 orphans. Further investigation of the surrounding area revealed that cutting down trees at the toe of a slope lead to this disaster [39].

The aim of this paper is to obtain slope maps of three locations within the area of Kuantan, Pahang which are Sungai Lembing, Pahang Matriculation College and Politeknik Sultan Ahmad Shah ‘POLISAS’, Kuantan by using unmanned aerial vehicle UAV or commercially known as drone. This focuses on the use of UAV for modern mapping compared to previous traditional method of mapping. Another scope of the work is to determine the measurement of these slopes such as perimeter, area, volume and more which are considered to support the main objectives to show the effectiveness of UAV for mapping. In addition, this paper also discusses the advantages of slope mapping using UAV compared to traditional method and which are proven to be the better method.

II. RESEARCH METHODOLOGY

This study consists of three locations within the area of Kuantan, Pahang which are Sungai Lembing, Pahang Matriculation College and POLISAS, Kuantan. The site area consists of different terrain profiles. This site is completely free from any distraction and obstacle on the air for UAV to freely move around. Figure 1 shows the map of Sungai Lembing, Figure 2 shows the map of POLISAS while Figure 3 shows map of Pahang Matriculation College.

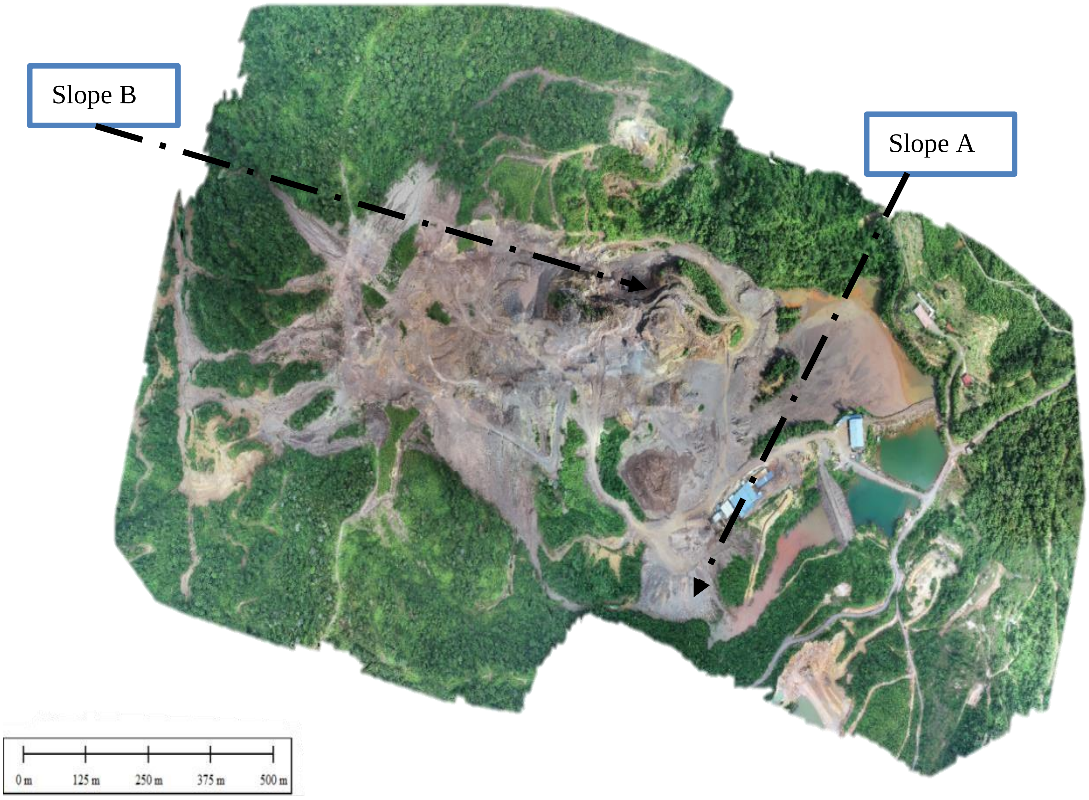


Figure 1: Sungai Lembing

2.1 DJI Inspire 2

The DJI Inspire 2 weight around 3.44 kg make it a powerful and high technology drone. This UAV has a speed of 94 km/h which make it pretty impressive. The max ascent speed is 6 m/s in sport mode and the max descent speed is 4 m/s. The length of this UAV is 42.7 cm, with height of 31.7 cm and width of 42.5 cm. DJI Inspire 2 has a maximum transmission distance of 7 km and is capable to deliver both 1080p and 720p video. Figure 4 show the image of DJI Inspire 2. Table 2 show the specification and features of DJI Inspire 2.

2.2 Image acquisition

The normal workflow accepted for image acquisition has been used by many researchers and practitioners. Following are the steps for image acquisition as in Figure 5. The results obtained from UAV monitoring will then be transferred into global mapper version 18.1 for further analysis. For these slope mapping, the average altitude used is 300 m from sea level which are set earlier before flight planning. The resolution used for these mapping is 4K (2160P). The datum used in this study is WGS84 (Projection UTM, Zone 48 (102° E – 108° E- Northern Hemisphere).

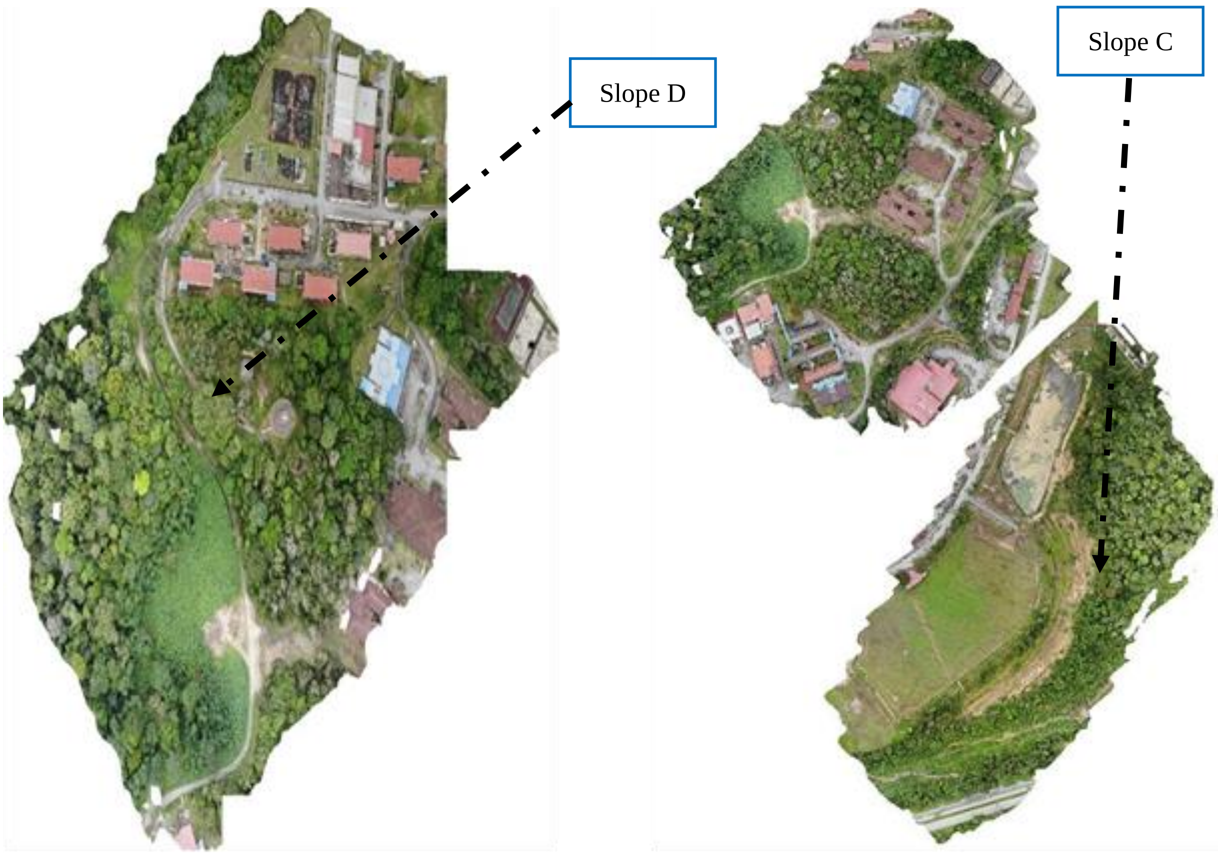


Figure 2: POLISAS, Kuantan

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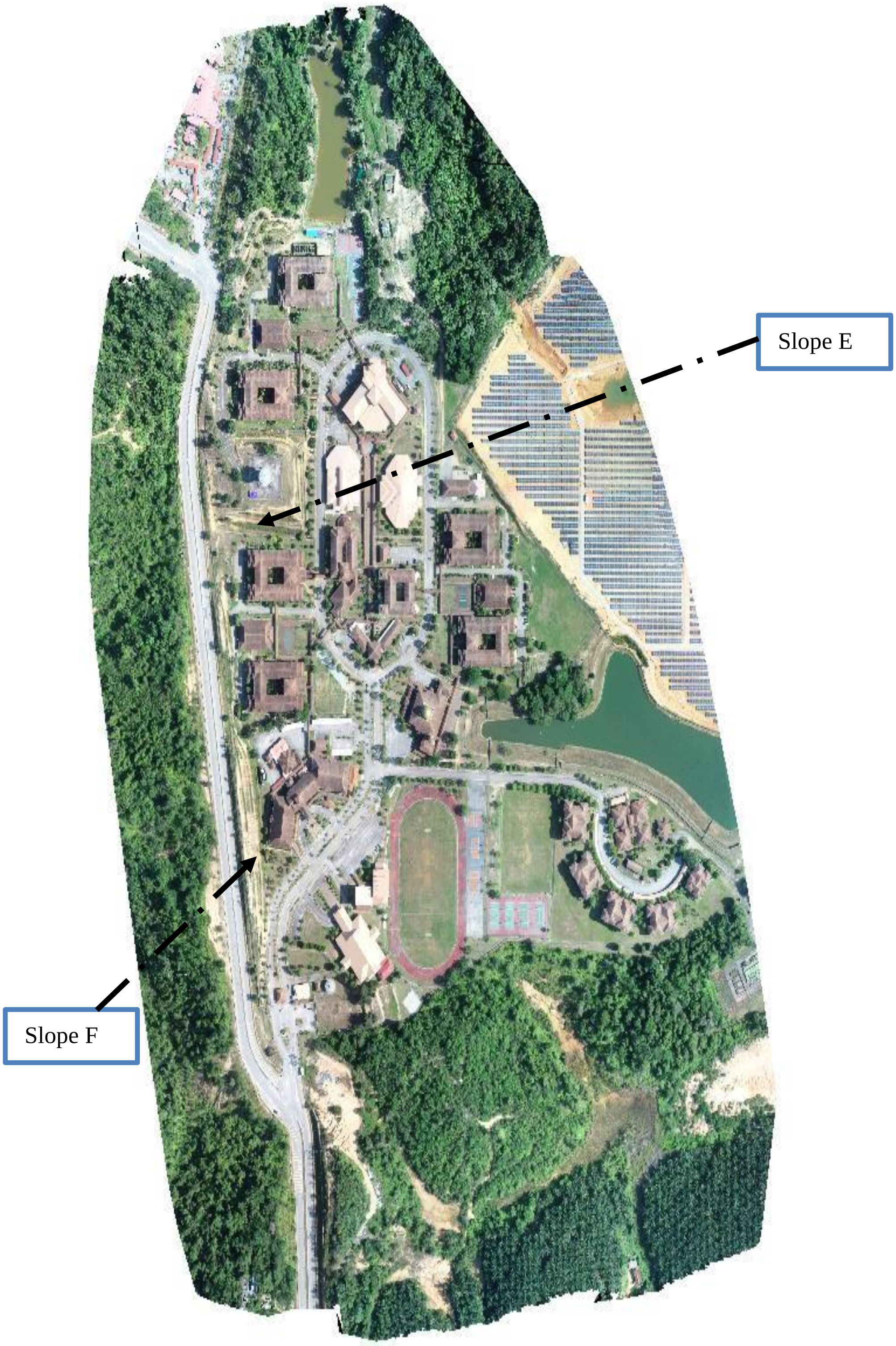


Figure 3: Pahang Matriculation College

Figure 4: DJI Inspire 2

Table 2: Specification of DJI Inspire 2

Parameters	Details
Flight time	25-27 minutes
Speed	94 km/h
Sensory range	30 m
Battery	98 Wh dual battery
Raw video recoding	Yes
Ports	USB and HDMI
Obstacle avoidance system	Yes
Control range	7 km
Video resolution	5.2K and 4K
Live View	1080P
Remote controller frequency	2.4 GHz and 5.8 GHz
Design material	Magnesium aluminium composite shell with carbon fibre arm

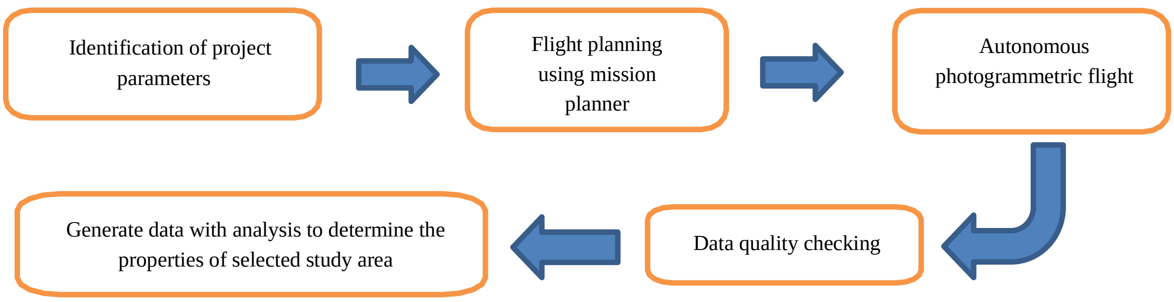
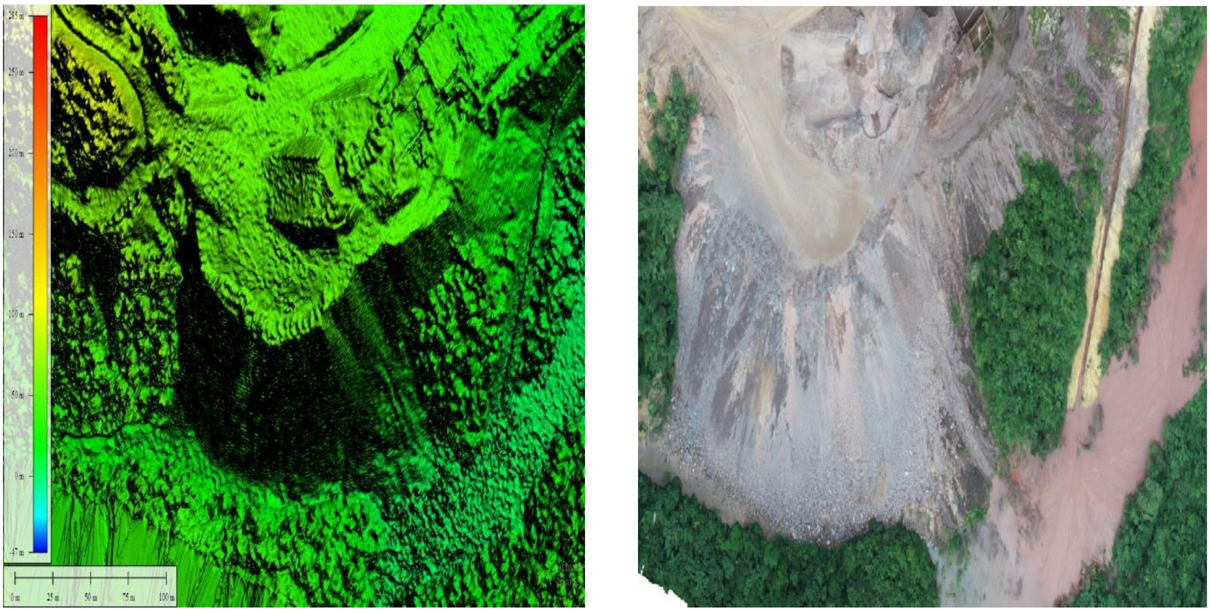


Figure 5: Workflow for data acquisition [12], [13]

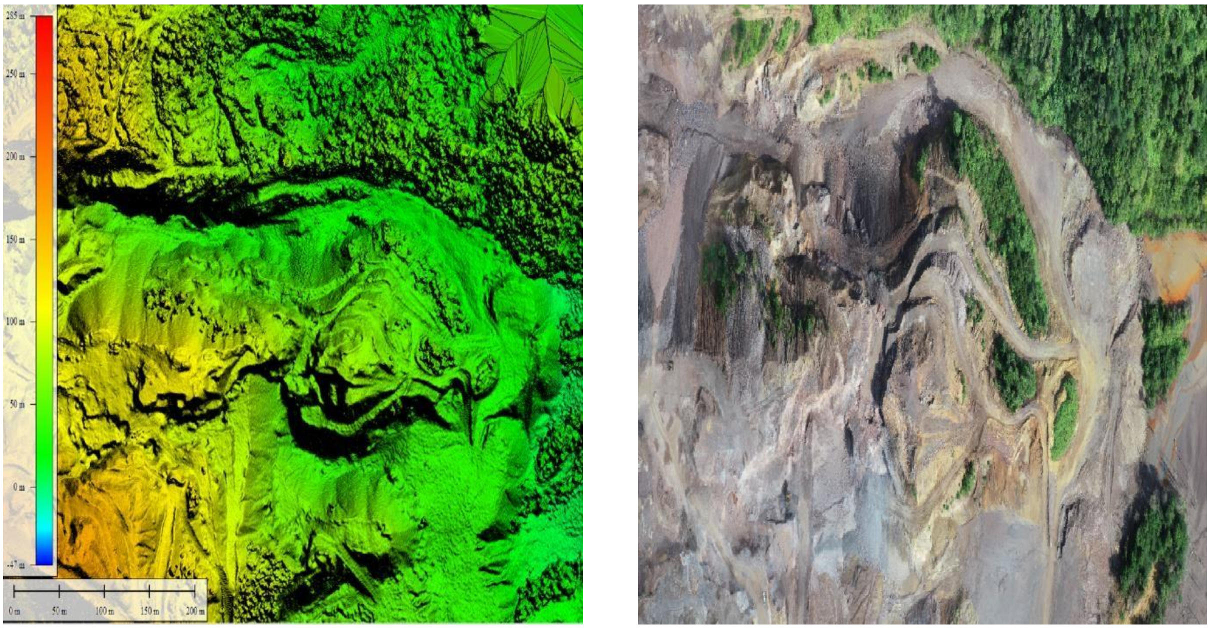
III. RESULTS AND DISCUSSION

The result of this study is presented in two types of images which are digital orthophoto and digital surface model (DSM). The ground control points (GCP) is explicitly insignificant to be used in this study as it does not give much error for the results obtained. The independent orthoimages are used to generate digital orthophoto in photogrammetric process. Figure 6 presents the image of area A, Figure 7 shows image of area B, Figure 8 presents the image of area C, Figure 9 shows image of area D, Figure 10 presents the image of area E and Figure 11 shows image of area F.



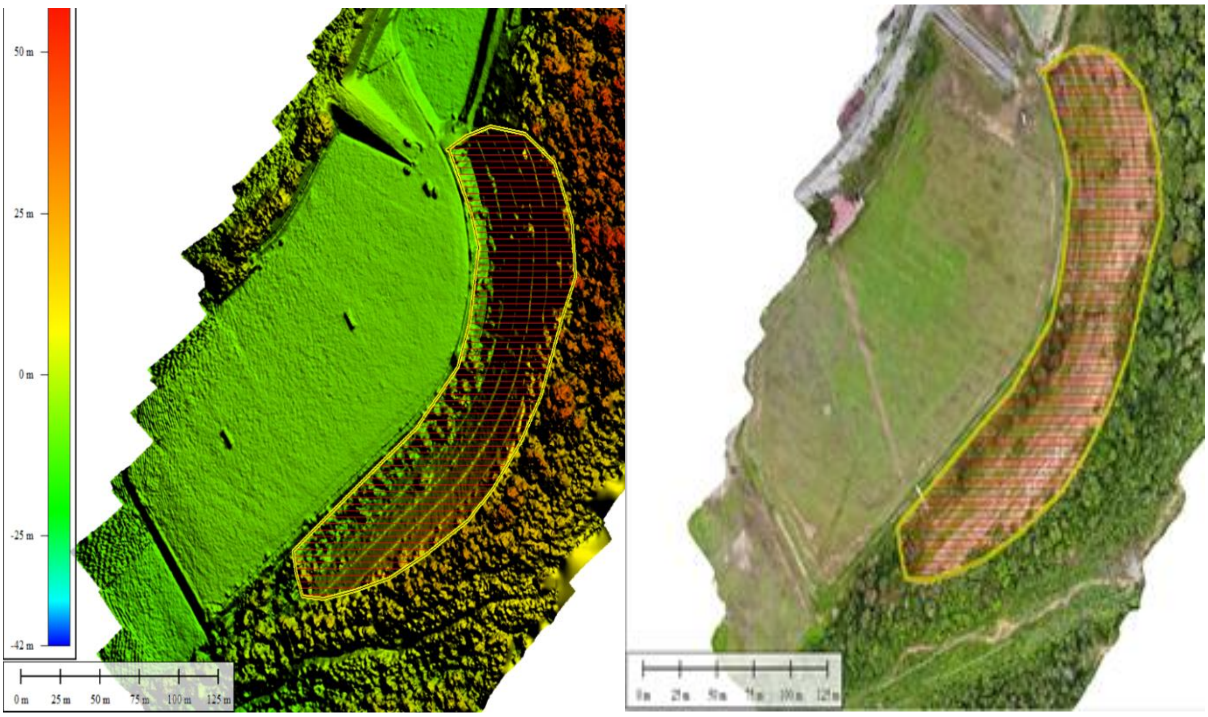
(a) (b)

Figure 6: (a) Digital surface model (DSM) of area A, (b) Digital orthophoto of area A



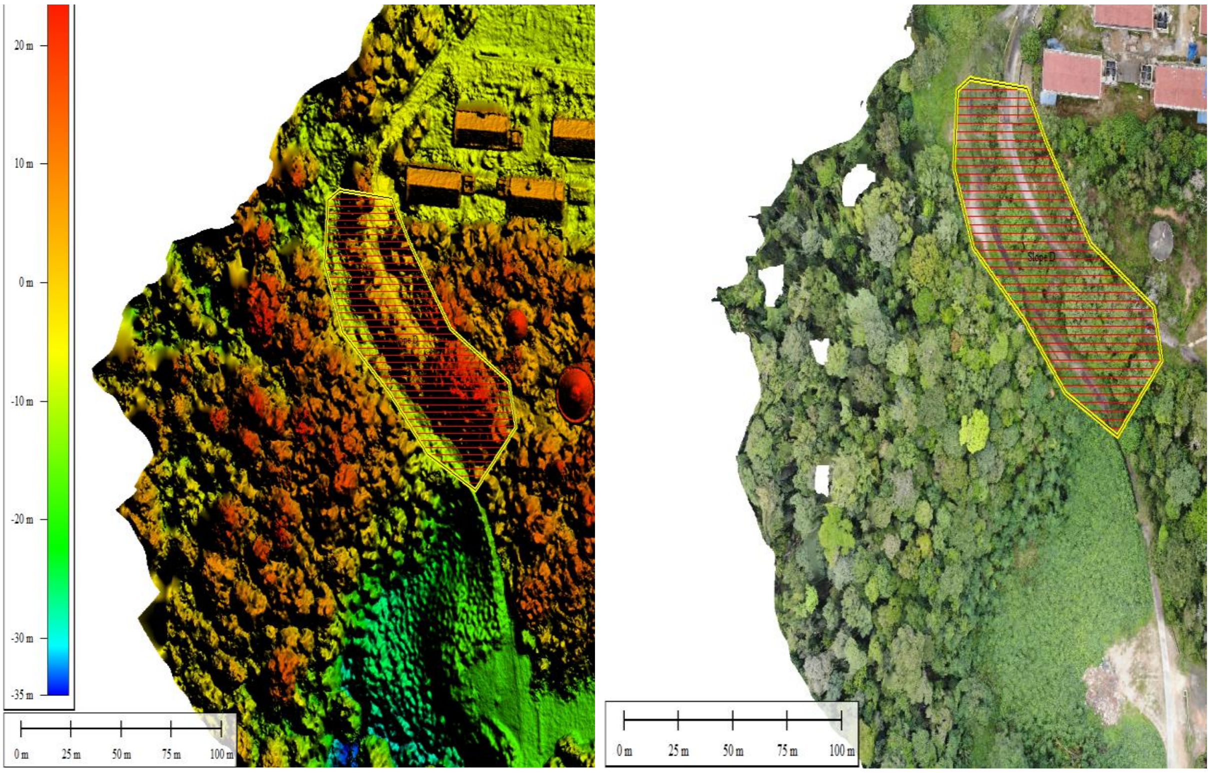
(a) (b)

Figure 7: (a) Digital surface model (DSM) of area B, (b) Digital orthophoto of area B



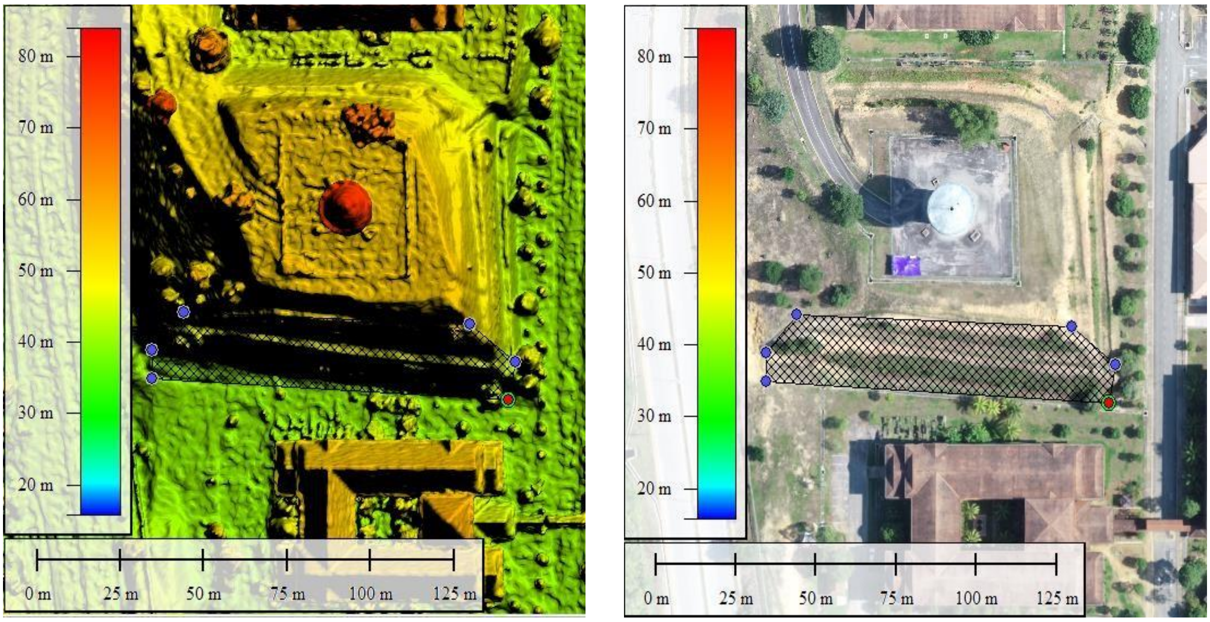
(a) (b)

Figure 8: (a) Digital surface model (DSM) of area C, (b) Digital orthophoto of area C



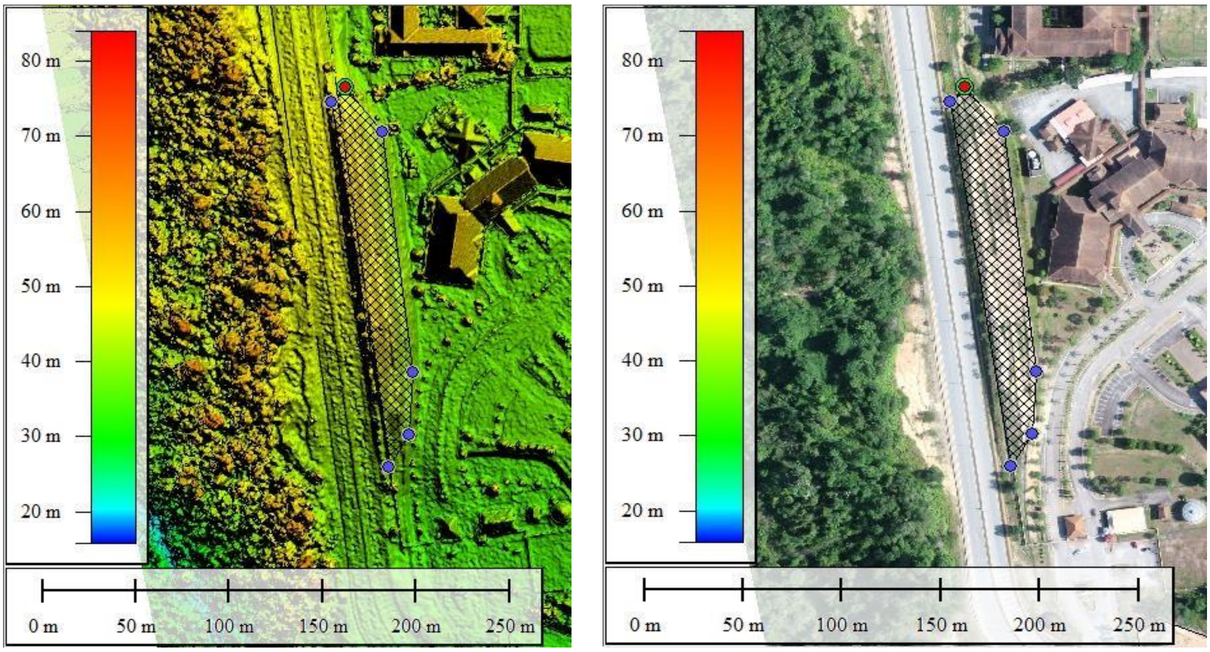
(a) (b)

Figure 9: (a) Digital surface model (DSM) of area D, (b) Digital orthophoto of area D



(a) (b)

Figure 10: (a) Digital surface model (DSM) of area E, (b) Digital orthophoto of area E



(a) (b)

Figure 11: (a) Digital surface model (DSM) of area F, (b) Digital orthophoto of area F

The application of unmanned aerial vehicle (UAV) not only limited for area mapping, but it can also help to determine the measurement of those areas such as perimeter, area, volume and more. The uses of global mapper software version 18.1 can meet the requirement needed in order to obtain the measurement of selected study area. The dimensions of all slopes (A, B, C, D, E and F) are shown in Figure 12, Figure 13, Figure 14, Figure 15, Figure 16 and Figure 17. Table 3 present the measurements of all slopes.

Figure 12: Slope A

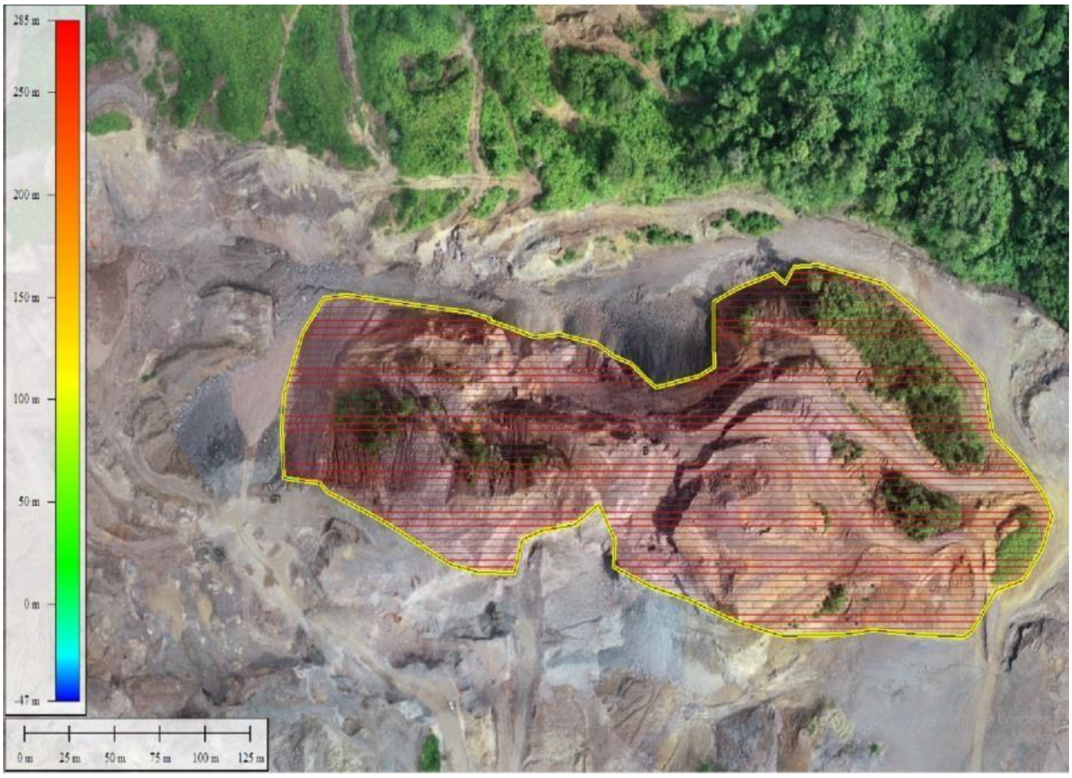


Figure 13: Slope B

Figure 14: Slope C

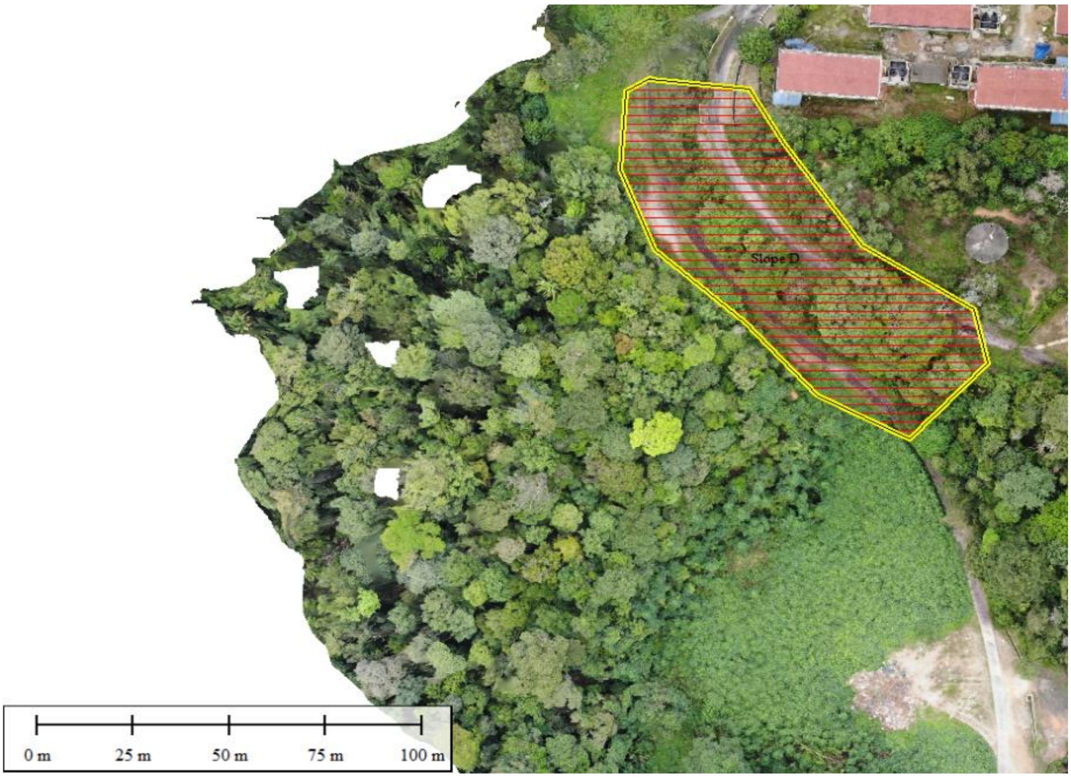


Figure 15: Slope D

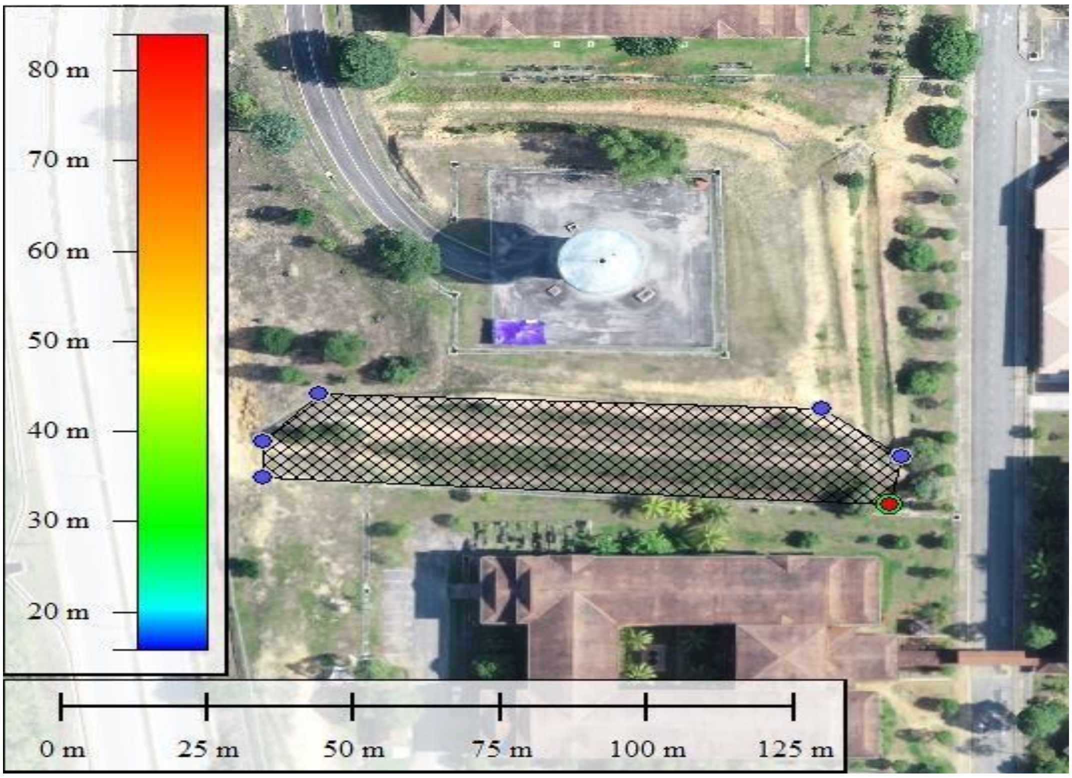


Figure 16: Slope E

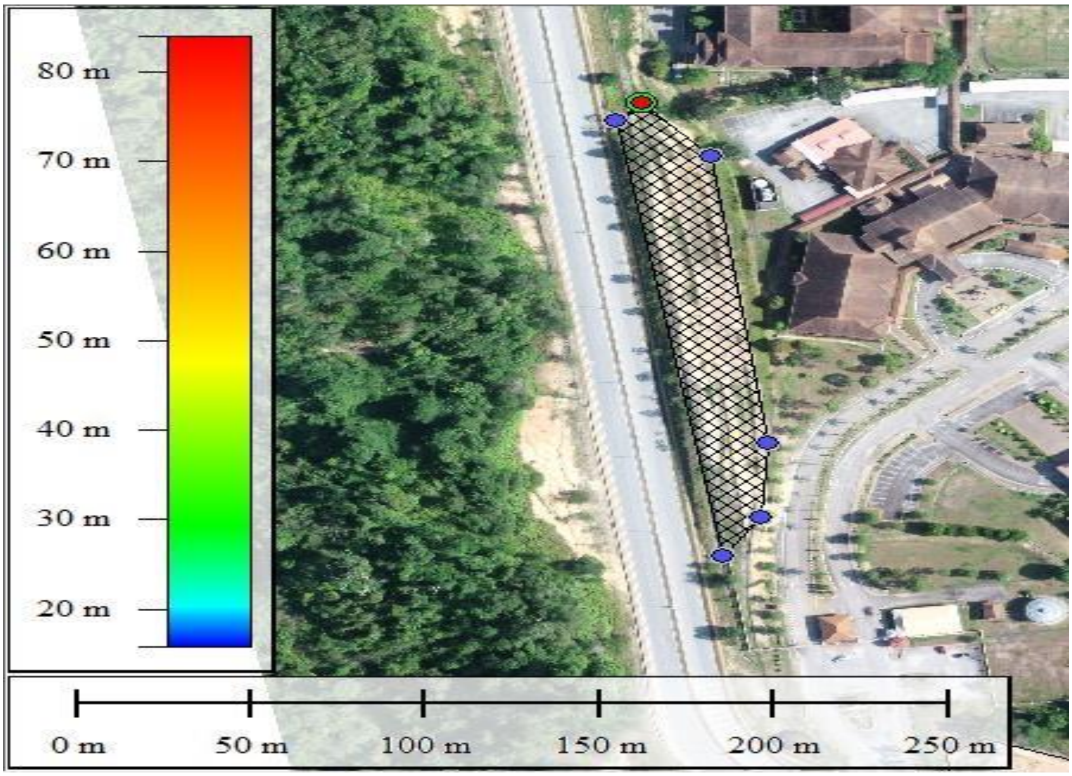


Figure 17: Slope F

Table 3: Measurement of slope A, B, C, D, E and F

Measurement	Slope A	Slope B	Slope C	Slope D	Slope E	Slope F
Cut Volume (m^3)	14128.36	464630.89	1683.08	3443.51	721.31	2761.80
Cut Area (m^2)	7890.00	41290.00	982.00	982.00	1174.00	3439.00
Fill Volume (m^3)	26900.13	1283.29	2304.76	2304.76	582.53	420.67
Fill Area (m^2)	9590.00	1478.00	829.00	829.00	910.00	634.00
Perimeter (m)	777.75	1018.00	366.64	366.64	243.52	243.52

Table 4 shows the comparison of slope mapping between Unmanned Aerial Vehicle (UAV) and traditional method. First the comparison in term of area scale where unmanned aerial vehicle (UAV) act as aerial photogrammetric technique to effectively generate medium to extra-large scale mapping and other diversified applications especially for a small area which has limited budget and time compare to traditional method which only generate small scale mapping.

The UAV method allows surveyors to do works in a short period of time and required minimum worker or only one worker which proven to be a better method of mapping compare to those suggested by Fitzpatrick [20] which using manned aircraft; Siebert and Teizer [22] which using tachymetry (theodolite) surveying techniques and [23], [24] which using rotary wing UAVs survey. They stated that this traditional method is more time consuming and required more workers.

This UAV technique is one of the alternatives for a faster way in data acquisition, easy and safe while according to Beretta *et al*. [6] using laser scanning; Sebbane [21] using GPS point survey; Siebert and Teizer [22] using tachymetry (theodolite) surveying techniques described that those method consume lots of time for data acquisition and processing, much complicated and unsafe to workers because of challenging site due to factor of topography.

UAV-acquired datasets have better resolutions in both temporal and spatial aspects with the high quality, cheaper and impressive level of details in the outputs compare using laser scanning survey method is expensive, generates low-quality products and unimpressive level of details in the outputs. Table 5 present the comparison of mapping between all three sites.

Table 4: Comparison of slope mapping using UAV and traditional method

Comparison	**Unmanned Aerial Vehicle (UAV) Method**	**Traditional Method**
Area	Medium to extra large	Small
Time consuming	Short	Long
Usability	Easy	Much Complex
Data quality	High	Low
Cost	Cheap	Expensive
Worker	Minimum (one is more than enough)	Maximum (depends on site)
Potential hazard to man	Safe	Unsafe (especially in high and hilly region)
Data acquisition	Fast	Slow

Table 5: Comparison of mapping between all three sites

Comparison	Sungai Lembing	POLISAS	Pahang Matriculation College
Time for image acquisition (minutes)	20	10	30
UAV Image Resolution	4K	4K	4K
Potential Hazard	None	None	None

IV. CONCLUSION

From this study, the use of UAV has proven to be very effective such as low costing, low time consuming, easily to operate and can gather huge amount of data within short time interval for slope mapping. This modern technology will help in research and also commercial works which make work easier and faster. In this study, with the combination of data from UAV and also established software provide researchers with important parameters and information about topography of study area. Other than that, the measurements of the study area such as its perimeter, area, volume and more can be obtain precisely. Mapping using UAV prove to give better impact when compare to mapping using previous traditional method.

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